

# Core Polarization with Variable Oscillator Length Parameters for Valence Particles

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## Abstract

We study quadrupole and monopole core polarization using harmonic oscillator wave functions but with different length parameters for the valence particle as compared to the core. We use perturbation theory with a delta interaction. The results also hold for a density dependent delta interaction [1]. We study how the amount of core polarization varies with the distance of the valence particle from the core.

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TABLE I: Quadrupole Core Polarization Ratio vs.  $x$ .

$x$	$RQ(x)$
0	0
0.1	0.394
$\sqrt{2/5}$	1.394
0.9	1.149
1	1
1.1	0.853
2	0.162
infinity	0

## I. THE QUADRUPOLE MODE

Our simple model consists of a valence  $p_{3/2}$  neutron relative to a  ${}^4He$  core. We use a delta interaction to polarize the core. The particle-hole combination excited by the  $p_{3/2}$  neutron is  $0d\ 0s^{-1}$ . We use an oscillator length parameter for the cor  $b_c$ .

$$(\hbar\omega = \hbar^2/(2mb^2) = 40.46/b^2) \quad (1)$$

We keep  $b_c$  fixed but we vary the oscillator length parameter  $b$  of the valence nucleon.

Using scaling properties of harmonic oscillator wave functions and the delta interaction we get a simple expression for the ratio of the core polarization contribution to the quadrupole moment of  ${}^5He$  for  $b(\text{valence})$  different from  $b_c$  to the case where they are equal.

The ratio for the quadrupole mode is given by

$$RQ(x) = x^2/(0.5 + 0.5x^2)^{3.5} \quad (2)$$

where  $x = b/b_c$ .

Although we expect only small deviations from  $x=1$  it is instructive to study the function for all  $x$ .

Since  $x = b/b_c$  when  $x$  is greater than one, the valence particle is further away from the core and when  $x$  is less than one the valence particle is closer to the core. For values of  $x$  close to one we see that the core polarization is enhanced when the valence particle moves

TABLE II: Monopole Core Polarization Ratio vs.  $x$

$x$	$RM(x)$
0	33.941
0.9	1.957
1	1
1.1	0.409
$\sqrt{3/2}$	0
$\sqrt{5/2}$	-0.282
infinity	0

into the core i.e. when the radius of the valence particle orbit is decreased. Conversely when the valence particle moves away from the core it's ability to polarize the core is diminished.

In studying the full function with increasing  $x$  we see that there is a maximum core polarization for  $x = \sqrt{2/5}$  (RQ=1.3938) after which RQ steadily decreases. Near  $x = 1$  RQ( $x$ ) is steadily decreasing as the valence particle moves away from the core.

## II. THE MONOPOLE MODE

For the monopole mode the particle hole pair is  $1s\ 0s^{-1}$ . Now the ratio is

$$RM(x) = (3 - 2x^2)/(0.5 + 0.5x^2)^{3.5} \quad (3)$$

We see that with increasing  $x$ , in the monopole case the core polarization also decreases especially near  $x=1$ . But then it vanishes when  $b = \sqrt{3/2} b_c$ , becomes negative beyond that, reaches an extremum at  $x = \sqrt{5/2}$  and goes to zero at infinity.

A motivation of this simple model comes from the fact that for neutron rich nuclei the valence neutrons can be very loosely bound. Consequently, their ability to polarize the core could be reduced.

## III. REFERENCES

- [1] J. Speth, L. Zamick and P. Ring, Nucl. Phys. A232, 1 (1974).